

Protocols



Phenology

Introduction



Why Study It

Every year, as conditions for plant growth improve, a wave of green spreads over the land surface and then retreats as conditions for plant growth decline. These waves are important because they are directly related to global carbon fixation and the amount of carbon dioxide (CO₂) in the atmosphere. The period between green-up and green-down or senescence is known as the growing season, and changes in the length of the growing season may be an indication of global climate change. For example, some scientists recently found that the growing season has increased in northern latitudes by eight days since the early 1980s. However, their conclusion is controversial because it was based only on satellite data. On-the-ground observations of plant green-up and green-down are needed to validate these types of satellite estimates.

Why Take Phenology Measurements

Estimates based on remote sensing data from satellites vary because of problems such as interference from small and large clouds, atmospheric haze, and other atmospheric properties that affect the greenness values that satellites detect. Other problems such as low sun angles at high latitudes, change of sun angle with seasons, poor viewing geometry, and aging of satellite detectors can affect scientist's estimates of greenness as well. GLOBE student observations are the only global network of ground-based plant phenology observations and will help scientists validate their estimates of global growing season changes that they derive using satellite data.

The Big Picture

Phenology is the study of living organisms' response to seasonal and climatic changes in their environment. Seasonal changes include variations in day length or duration of sunlight, precipitation, temperature and other life-controlling factors. The focus of this investigation is plant phenology during green-up and green-down. The plant growing season generally corresponds to the period between green-up and green-down. Green-up and green-down can be used to examine regional and global vegetation patterns, year-to-year trends, and vegetation responses to climate change.

Plant green-up is initiated when dormancy (a state of suspended growth and metabolism), is broken by environmental conditions such as longer hours of sunlight and higher temperatures in temperate regions, and rains and cooler temperatures in deserts and semi-arid areas. As plants begin green-up, leaf chlorophyll absorbs sunlight for photosynthesis. Photosynthesis fixes carbon dioxide from the atmosphere, using the carbon atoms to form plant tissue. Carbon dioxide, a greenhouse gas that has increased steadily over the last few decades, may promote global climate warming. To help in computer models of atmospheric carbon dioxide, scientists need accurate information about the timing and duration of global greenness (when photosynthesis is actively going on during daylight). This is especially important because the length of the plant growing season seems to have increased dramatically in some parts of the globe. Monitoring the length of the growing season is important for detecting climate change and for understanding the carbon cycle – one of the key biogeochemical cycles discussed in the introduction.

As plants photosynthesize, they also transpire water from the soil, through the roots and plant stems, and out the leaves into the atmosphere. This affects atmospheric temperature and

humidity, and soil moisture. With green-down, plant transpiration of water decreases; plants reduce water loss when their water supply is greatly limited during winters for deciduous plants and during dry spells for desert plants. Therefore, knowing the timing of green-up and green-down is important for understanding the global water cycle. Scientists also use greenness estimates from satellites to map wild fire danger. High greenness areas represent lower wildfire danger, while low greenness areas represent higher wildfire danger. Scientists studying migrations of animals such as caribou, use greenness maps to help them understand animal population migration patterns.

As discussed in the *Land Cover Investigation*, healthy green plants reflect much more near-infrared sunlight than visible light. Remote sensing scientists use visible and near-infrared reflectance estimates from satellites to derive a greenness index. New and better satellite data are now available from the MODIS (Moderate Resolution Imaging Spectrometer) instrument on board NASA's Terra satellite launched in December 1999. This satellite is part of a coordinated international effort to use many satellites and instruments to study the global environment. However, scientists will need GLOBE student observations of plant phenology to help them validate estimates of greenness from around the globe taken by these and other satellite systems.

Measurement Logistics

Protocol	Green-Up	Green-Down
What procedures are performed?	Observe and report dates of green-up and leaf growth	Observe and report dates of green-down color changes
Where are procedures conducted?	Plant Phenology Study Site; Site close to Atmosphere and Soil Moisture and Temperature Study Sites is preferred	
When are procedures conducted?	Twice weekly, starting at least two weeks before initial budburst until leaf length stops increasing	Twice weekly, starting two weeks before initial green-down until leaf color change is complete or leaves fall off
What equipment is needed?	Permanent marker, ruler with mm scale, compass, camera, data sheets, plant identification keys, calculator (optional)	Permanent marker, GLOBE Plant Color Guide, compass, camera, plant identification keys, data sheets



Green-Up and Green-Down Site Selection

1. Your plant phenology site should be in an area where green-up of native plants is due to climatic factors such as increased temperature or precipitation. Watering and fertilization alter plants' green-up and green-down cycles, and the data would not be representative of natural vegetation and local climate connections. Buildings absorb solar radiation and shelter sites from wind. Therefore, avoid sites near buildings or where watering or fertilization is done. For the phenology protocols, near means that the plant is closer to a building than the height of the building. To determine if the building is too close, stand at the plant and sight the top of the building through your clinometer. If the angle is greater than 45° , the building is too close.
2. Non-native species, called exotics, have green-up and green-down cycles that may not be tied to the local climate. Often this is because exotics have not evolved to survive in the local climate. If you are unsure which plants are natives or have evolved to grow in a climate regime similar to yours, ask a local greenhouse or agricultural extension agent, or the appropriate staff at a local college or university.
3. Your green-up and green-down site must be accessible so that students can visit the site at least twice a week. It may be the same as a Quantitative Land Cover Sample Site or your Atmosphere Study Site. Be sure to determine the location of your site by identifying the latitude, longitude and elevation following the *GPS Protocol*.
4. Because the results of your green-up and green-down measurements may be related to temperature and precipitation data from the *Atmosphere Investigation* and soil moisture and temperature data from the *Soil Investigation*, it is better to choose a site close to the Atmosphere and Soil Moisture Study Sites. The local topography can cause weather to vary even within short distances. This is particularly true in mountainous and coastal regions. The horizontal distance between the Phenology and Atmosphere and Soil Moisture Sites should be less than 2 kilometers and the elevation differences less than 100 meters, so that you can see whether your atmosphere data correlates with your green-up and green-down data.
5. Green-up and green-down detected by satellites are influenced mostly by a few dominant overstory plant species. These will be the species with the largest share of canopy coverage. If you are using a Quantitative Land Cover Site, you already know the dominant species. If you are using a different site, use the one to three over-story species that are dominant for your region. These over-story plants may be coniferous trees, broadleaf trees, broadleaf shrubs, or grasses. For phenology measurements you should choose a deciduous plant so, if the dominant plant species are all evergreen conifers, use the under-story broadleaf shrubs as your green-up plants. For example, if your study site is 90 percent white pine (a coniferous tree) and 10 percent sugar maple (a broad leaf tree), use the sugar maple trees as the study plants.
6. Scientifically, it is most useful if the tree or shrub branch used for the *Green-Up Protocol* is the same as the one used for the *Green-Down Protocol*. However, you may do only the Green-Up or Green-Down measurements or you may use different branches or even different sites if this is necessary to match your educational requirements. If you use different sites for green-up and green-down, create a site definition for each.
7. Since a change in plant growing season may be due to a change in climate, students at your school should try to use the same site and the same plant species consistently, year after year.

Tree and Shrub Green-Up and Green-Down Site Selection

Field Guide

Task

Define the site for green-up and green-down measurement of trees and shrubs.

What You Need

- | | |
|---|---|
| <input type="checkbox"/> <i>Green-Up and Green-Down Site Definition Sheet</i> | <input type="checkbox"/> Dichotomous keys and/or other local species guides |
| <input type="checkbox"/> Pencil or pen | <input type="checkbox"/> GPS receiver |
| <input type="checkbox"/> Compass | <input type="checkbox"/> <i>GPS Data Sheet</i> |
| <input type="checkbox"/> Flagging tape or other durable identification | <input type="checkbox"/> <i>GPS Protocol Field Guide</i> |

In the Field

1. Complete the top of the *Green-Up and Green-Down Site Definition Sheet*.
2. Select one tree or shrub. The tree or shrub should be among the dominant native species in your area, deciduous, and easily accessible.
3. Select a healthy and relatively large branch on the south side of the plant in the Northern Hemisphere or the north side of the plant in the Southern Hemisphere. Use a compass or GPS receiver to determine direction. If a lower branch is chosen, it should be on the edge of the stand of trees or shrubs since branches inside a stand may experience a different microclimate due to shading.
4. Identify genus and species using field guides or the help of plant specialists. Record the genus and species on the *Green-Up and Green-Down Site Definition Sheet*.
5. Mark the branch with flagging tape or some other durable identification. Label the flagging tape with a unique number and your name/group name, school name and class.
6. Take a GPS measurement following the *GPS Protocol*.

Grass Green-Up and Green-Down Site Selection

Field Guide

Task

Define the site for green-up and green-down measurement of grasses.

What You Need

- | | |
|---|---|
| <input type="checkbox"/> <i>Green-Up and Green-Down Site Definition Sheet</i> | <input type="checkbox"/> <i>GPS Protocol Field Guide</i> |
| <input type="checkbox"/> Pencil or pen | <input type="checkbox"/> Nails or stakes or other durable identifiers |
| <input type="checkbox"/> GPS receiver | <input type="checkbox"/> Meter stick or tape measure |
| <input type="checkbox"/> <i>GPS Data Sheet</i> | <input type="checkbox"/> Dichotomous keys and/or other local species guides |

In the Field

1. Complete the top of the *Green-Up and Green-Down Site Definition Sheet*.
2. Identify genus using field guides or help of plant specialists. Record the genus on the *Green-Up and Green-Down Site Definition Sheet*.
3. Select a one-meter square area dominated by grass plants. Mark your one-meter square plot with nails or stakes or other durable identifiers.
4. Take a GPS measurement following the *GPS Protocol*.

Green-Up Protocol



Welcome

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Protocols

Learning Activities

Appendix

Purpose

To observe plant green-up and report data that will be used by scientists to validate satellite estimates of the beginning of the plant growing season

Student Outcomes

Students will learn stated key concepts and be able to apply process skills in understanding patterns of green-up among plants.

Overview

Students monitor budburst and growth of leaves of selected trees, shrubs, or grasses. Species chosen should be native, deciduous, and dominant in your area.

Time

Field time: 20 minutes excluding travel time.

Level

All

Frequency

At least twice a week beginning two weeks prior to the anticipated start of green-up, if possible

Key Concepts

- Green-up differs among plant species.
- Green-up differs among locations.
- Green-up is related to climate.
- Green-up marks the start of photosynthesis for the season.

Skills

- Estimating dominant plant species*
- Identifying plant species (advanced level)*
- Observing leaf growth*
- Making leaf measurements*
- Recording leaf measurement data*
- Calculating percentages*

Materials and Tools

- Ruler with mm marks
- Flagging tape, 1 label per student
- Pencil or pen
- Green-Up Data Sheet*
- Grass Green-Up Field Guide* and/or *Tree and Shrub Green-Up Field Guide*
- Dichotomous keys and/or other local species guides
- Compass
- Camera
- Calculators (optional)

Preparation

Review dominant plant species of school's GLOBE Study Site.

Prerequisites

- Green-Up Cards Learning Activity*
- Budburst Sneak Preview Learning Activity*
- Practice mm length measurements with ruler.
- Knowledge of common plant species at the site

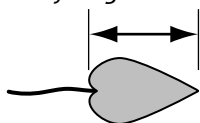


Teacher Support

Helpful Hints

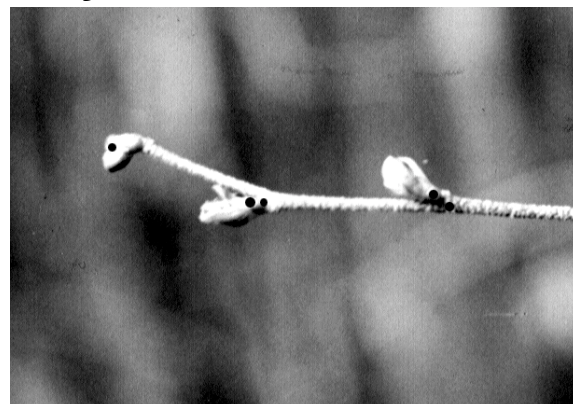
1. Students should complete the *Green-Up Cards* and *Sneak Preview of Budburst* learning activities prior to budburst and green-up.
2. Check with local sources for average green-up dates to help determine when to start observations. In areas where snow is common, observations should begin immediately after snow melt. For each visit where no green-up was observed for the study plant, students should fill in the observation date in the *Pre-Green-Up Section* of the *Green-Up Data Sheet*.
3. Sometimes green-up can last past the end of the school year. To be scientifically useful, measurements should be taken of the leaf until it reaches maturity. Enlisting the help of parents or other members of the community may encourage and support the students to continue taking the measurements after the school year ends.
4. For green-up observations, leaf length is from the leaf base to the leaf tip. Do not include the leaf stem or petiole as part of the leaf length measurement.

Figure EA-P-1: Leaf Length Measured without Petiole



5. Ideally, each student should visit his/her plant at least two times a week to check for start of green-up and continue observing until leaf growth plateaus. For trees or shrubs, the start of green-up occurs when one of the four sample buds (selected for observation) swells and you can see tiny green leaves starting from the bud. Some of the buds on your branch may not green-up on exactly the same day. For grasses, the start of green-up occurs when any initial green grass shoot is first observed. See the *Green-Up Cards* learning activity for pictures of grass shoot initiation.

Figure EA-P-2: Sample Buds Marked with Permanent Markings



6. For most areas of the world, there is only one green-up and green-down cycle. However, there are places where multiple wet and dry seasons can occur in a single year, resulting in multiple green-up and green-down cycles. Because of this possibility, we are asking you to report which cycle you are observing. If there is only one cycle, then you report green-up cycle 1. The onset of the first green-up after 1 January is considered green-up cycle 1.
7. There are two data sheets for green-up; one for grasses, the other for trees and shrubs. For each tree and shrub leaf students report the state of leaf from dormancy to maturity. Report “dormant” if the bud is unchanged and still in its dormant state during cold or dry seasons. Report “swelling” if the bud is getting bigger. Report “budburst” when the bud first opens and the green tips of leaves can be seen. After budburst, students measure the length of each leaf and report the length in millimeters. If the leaf gets lost for some reason, report “lost”.

For grasses, report “no shoot” before the leaves of grass can be seen, the length in millimeters after the shoot appears and “lost” if something happens to the marked leaves.

Here are examples of completed tree and shrub green-up data sheet and a grasse green-up Data Sheet.



Tree and Shrub Green-Up

Date (day and month)	Leaf 1 (Dormant, Swelling Budburst, Length (mm), Lost)	Leaf 2 (Dormant, Swelling Budburst, Length (mm), Lost)	Leaf 3 (Dormant, Swelling,, Budburst, Length (mm), Lost)	Leaf 4 (Dormant,Swelling, Budburst, Length (mm), Lost)	Reported to GLOBE
3 March	dormant	dormant	dormant	dormant	<input type="checkbox"/>
6 March	dormant	dormant	dormant	dormant	<input type="checkbox"/>
11 March	swelling	swelling	swelling	dormant	<input type="checkbox"/>
14 March	budburst	budburst	swelling	Swelling	<input type="checkbox"/>
18 March	2	4	budburst	Budburst	<input type="checkbox"/>
22 March	6	10	5	6	<input type="checkbox"/>
25 March	12	15	10	12	<input type="checkbox"/>
29 March	20	22	18	19	<input type="checkbox"/>
2 April	30	32	25	28	<input type="checkbox"/>
5 April	38	lost	36	38	<input type="checkbox"/>
8 April	45		42	44	<input type="checkbox"/>
11 April	45		44	44	<input type="checkbox"/>
14 April	45		44	44	<input type="checkbox"/>
					<input type="checkbox"/>

Grass Green-Up

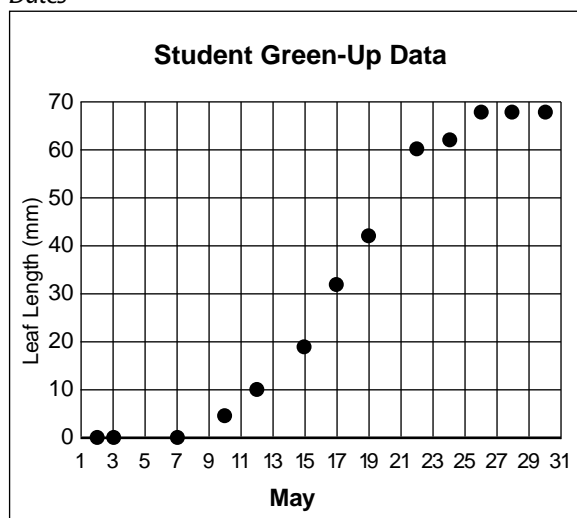
Date (day and month)	Leaf 1 (No shoot, length (mm), or lmost)	Leaf 2 (No shoot, length (mm), or lost)	Leaf 3 (No shoot, length (mm), or lost)	Leaf 4 (No shoot, length (mm), or lost)	Reported to GLOBE
10 April	No shoot	No shoot	No shoot	No shoot	<input type="checkbox"/>
13 April	2	3	No shoot	No shoot	<input type="checkbox"/>
17 April	8	10	5	6	<input type="checkbox"/>
20 April	18	20	15	18	<input type="checkbox"/>
24 April	29	27	lost	30	<input type="checkbox"/>
27 April	36	35		40	<input type="checkbox"/>
1 May	48	50		55	<input type="checkbox"/>
4 May	58	50		55	<input type="checkbox"/>
8 May	58	50		55	<input type="checkbox"/>
					<input type="checkbox"/>
					<input type="checkbox"/>
					<input type="checkbox"/>

Check the last column on the green-up Data Sheet when you report your observations to GLOBE.



8. After each green-up observation, students should graph the leaf length (on the y- or vertical axis) with date (on the x- or horizontal axis). Green-up is complete on the date when leaf length stops increasing (two consecutive observations of the same leaf length and the leaf length graph plateaus.)

Figure EA-P-3: Sample Graph of Leaf Length on Different Dates



After the completion of leaf growth, students should calculate the percent of leaf growth for each observation date. For example, if the leaf was 10 mm long at one observation time and the mature leaf length is 200 mm, then the percent of total leaf growth would be calculated as $10 \text{ mm} / 200 \text{ mm} \times 100 = 5\%$. Calculations of percent leaf growth allow students to compare leaves that have different lengths at maturity. This is sometimes called normalization of data.

Student Support

Scientific Justification

Carbon dioxide is an important greenhouse gas in our atmosphere.

The pattern of atmospheric carbon dioxide is closely linked to the pattern of global plant green-up. Atmospheric carbon dioxide decreases during the plant growing season (when plants are photosynthesizing) and increases when plants are not photosynthesizing.

The greenness values detected by satellite sensors are important for scientists studying global carbon dioxide changes. The greenness values are also important in mapping wildfire danger and for studying migration of wildlife such as caribou and waterfowl.

Satellites only give scientists estimates of when plants green-up across the globe. These estimates have many problems. For example, some satellite data are incorrect due to clouds and aerosols reducing the greenness value detected by the satellite sensor. It would be very time-consuming and expensive for scientists to travel around the globe twice a week to observe where plants are green and where they have not yet greened-up. GLOBE schools can be a great help since they are already well distributed around the globe and you can report simple observations of budburst and green-up.

Synthesis Questions

Is there a relationship between air temperature and budburst dates reported for the GLOBE schools in your region?

How does plant green-up affect soil water?

What other animals (butterflies, waterfowl, songbirds) arrive after plants green-up, when, and why?

Does the timing of green-up occur earlier or later at higher elevations in your region? Why?

Does the timing of green-up occur earlier or later inland or near the coast in your region? Why?

Tree and Shrub Green-Up Protocol

Field Guide

Task

Observe and record green-up in trees and shrubs.

What you Need

First visit only

- | | |
|--|--|
| <input type="checkbox"/> Green-Up Data Sheet | <input type="checkbox"/> Fine-Tip Permanent Marker |
| <input type="checkbox"/> Pencil or pen | <input type="checkbox"/> Camera |
| <input type="checkbox"/> Ruler with mm units | <input type="checkbox"/> Compass |

Every visit

- | | |
|--|--|
| <input type="checkbox"/> Green-Up Data Sheet | <input type="checkbox"/> Ruler with mm units |
| <input type="checkbox"/> Pencil or pen | |

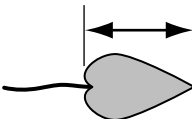
In the Field

First time only/getting started

1. Complete the upper portion of your data sheet.
2. For the selected tree or shrub, locate the bud at the end of the branch. Label this bud by marking one dot on the branch next to the bud.
3. Locate the three other buds closest to this bud. Label these buds by marking two, three, or four dots next to them.
4. Take a photograph from the center of your site looking in the north, south, east, and west directions.

Every visit

1. Examine each bud.
 - Record “dormant” if the bud is unchanged.
 - Record “swelling” if the bud is getting bigger.
 - Record “budburst” the first day you see the green tips of leaves.
 - Record “lost” if something happens to the bud and you cannot continue observations.
2. After each budburst, use a ruler to measure the length of the leaf or leaves. Do not include leaf stem or petiole in your leaf measurements.



3. Measure the leaves until the leaf length stops increasing. Different leaves may stop growing at different dates.

Grass Green-Up Protocol

Field Guide

Task

Observe and record plant green-up in grasses.

What You Need

First visit only

- | | |
|---|--|
| <input type="checkbox"/> <i>Green-Up Data Sheet</i> | <input type="checkbox"/> Ruler with mm units |
| <input type="checkbox"/> Pencil or pen | <input type="checkbox"/> Camera |
| <input type="checkbox"/> Fine-Tip Permanent Marker | <input type="checkbox"/> Compass |

Every visit

- | | |
|---|--|
| <input type="checkbox"/> <i>Green-Up Data Sheet</i> | <input type="checkbox"/> Ruler with mm units |
| <input type="checkbox"/> Pencil or pen | <input type="checkbox"/> Fine-Tip Permanent Marker
(until four new grass shoots have been marked) |

In the Field

First time only/getting started

1. Complete the upper portion of your data sheet.
2. Before new grass shoots emerge, take a photograph in the north, south, east, and west directions.

Every visit

1. Look for new green grass shoots.
2. Mark the base of the first grass shoot with a single dot.
3. Mark the second shoot with two dots, the third with three dots and the fourth shoot with four dots.
4. Use the ruler to measure the length of the shoots to the nearest millimeter.
5. Measure the leaves until the leaf length stops increasing.



Frequently Asked Questions:

1. Will the marker hurt the bud?

Do not mark the bud itself. Mark the woody branch next to it. That way you will not hurt the plant.

2. What do you mean by a relatively large branch?

Use your judgement. Each branch should be healthy and large relative to the other branches on the tree or shrub. You want the branch to still be there next year. Be careful not to damage the branch during the labeling and measurements.

3. What if a branch breaks during the study?

Continue your observations by teaming up with other students and observing their branch.

4. Will all the buds start to swell at the same time?

No. Some of the buds on your branch may not green-up on exactly the same day as the terminal bud.

5. Should I look at the same buds from year to year?

You should observe the same branch, which will typically have new terminal buds each year.

6. What if needle-leaved trees are the abundant vegetation?

Usually there are understory deciduous shrubs that can be used instead. For example, Snowberry in Douglas Fir, Gamel Oak in Ponderosa Pine. Typically these deciduous plants are what the satellites are detecting as Green-up. The Green-up of conifers is a subtle process and not easily observed. Note that the GLOBE Special Measurement of Budburst may be done on needle-leaved trees.



7. What if multiple leaves emerge from a single bud after the bud bursts open?

Choose one of the leaves and mark it with the permanent marker. Take measurements of the marked leaf.

8. How do I mark the grass shoots if they start on the same day?

Mark the base of the four longest grass shoots that appear at the earliest date.

9. What do I do if on the first day I see shoots, I see more than four? How do I select the shoots to study?

Mark the base of the four longest grass shoots that appear on the first day.

10. How long will it take for a leaf to mature?

That depends. It may take a week in Alaska with 18 hours of sunlight during Green-up. In other locations it may take a month or more.

11. What if there are grass shoots the first day when I go to take a picture of the site?

Mark the base of the four longest grass shoots that are present on this day.



Green-Down Protocol

Welcome

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Appendix

Purpose

To observe plant green-down and report green-down data to help validate estimates of the end of the plant growing season

Student Outcomes

Students will learn stated key concepts and be able to apply process skills in understanding patterns of green-down among plants.

Overview

Students monitor the change in color of selected leaves of trees, shrubs or grasses.

Time

30 minutes excluding travel time

Level

All

Frequency

At least twice a week beginning two weeks prior to the anticipated start of green-down, continuing until plant color change has ended or leaves have dropped off

Key Concepts

- Green-down differs among plant species.
- Green-down differs among locations.
- Green-down is related to climate.
- Green-down marks the end of the growing season and the cessation of photosynthesis.

Skills

- Identifying* signs of the end of the plant growing season
- Observing* seasonal leaf changes
- Recording* data
- Identifying* plant species (advanced level)
- Estimating* the dominant leaf color

Materials and Tools

- Flagging tape, 1 label per student
- Compass
- Camera
- Pencils
- GLOBE Plant Color Guide
- Green-Down Data Sheet*
- Fine-tip permanent marker

Preparation

Review dominant plant species of school's GLOBE Study Site.

Prerequisites

Estimating Cloud Cover: A Simulation (from *Atmosphere Investigation*)



Teacher Support

Helpful Hints

1. If lower branches are observed, try to sample them from the edge of the stand of trees or shrubs since branches inside a stand may experience a different microclimate due to shading.
2. Students should complete the *Estimating Cloud Cover: A Simulation Learning Activity* in the *Atmosphere Investigation* prior to observing green-down. Students will estimate percentage of leaf colors in the green-down observations.
3. Students should start their observations at least two weeks before expected green-down.
4. In some locations, the end of leaf color change will mark the end of the reporting period.
5. For most areas of the world, there is only one green-up and green-down cycle. However, there are places where multiple wet and dry seasons can occur in a single year, resulting in multiple green-up and green-down cycles. Because of this possibility, we are asking you to report which cycle you are observing. If there is only one cycle, then you report green-down cycle 1. The onset of the first green-down after 1 January is considered green-down cycle 1.
6. For each observation, students record the color of the leaf using the GLOBE Plant Color Guide, or if the leaf has fallen or been snow covered. If a leaf has fallen, then no more observations can be made for that leaf. Depending on the snow event, reporting may end as well. Here is an example of a completed Data Sheet.



Tree, Shrub, and Grass Green-Down

Date (day and month)	Leaf 1 (Color, fallen snow covered)	Leaf 2 (Color, fallen snow covered)	Leaf 3 (Color, fallen snow covered)	Leaf 4 (Color, fallen snow covered)	Reported to GLOBE
30 September	5 G 7/4	5 G 7/4	5 G 7/4	5 G 7/4	<input type="checkbox"/>
3 October	5 G 7/4	5 G 7/4	5 G 7/4	2.5 Y 8/6	<input type="checkbox"/>
7 October	5 G 7/4	2.5 Y 8/6	5 G 7/4	2.5 Y 8/6	<input type="checkbox"/>
11 October	5 G 7/4	2.5 Y 8/6	2.5 Y 8/6	2.5 Y 8/6	<input type="checkbox"/>
14 October	5 G 7/4	2.5 Y 8/6	2.5 Y 8/6	2.5 Y 8/6	<input type="checkbox"/>
16 October	2.5 Y 8/6	2.5 Y 8/6	2.5 Y 8/6	2.5 Y 8/6	<input type="checkbox"/>
20 October	2.5 Y 8/6	2.5 Y 8/6	2.5 Y 8/6	7.5 YR 6/4	<input type="checkbox"/>
23 October	2.5 Y 8/6	2.5 Y 8/6	2.5 Y 8/6	7.5 YR 6/4	<input type="checkbox"/>
27 October	2.5 Y 8/6	2.5 Y 8/6	2.5 Y 8/6	7.5 YR 6/4	<input type="checkbox"/>
30 October	2.5 Y 8/6	2.5 Y 8/6	7.5 YR 6/4	7.5 YR 6/4	<input type="checkbox"/>
4 November	2.5 Y 8/6	7.5 YR 6/4	7.5 YR 6/4	fallen	<input type="checkbox"/>
6 November	2.5 Y 8/6	7.5 YR 6/4	7.5 YR 6/4		<input type="checkbox"/>
11 November	7.5 YR 6/4	7.5 YR 6/4	7.5 YR 6/4		<input type="checkbox"/>
14 November	7.5 YR 6/4	7.5 YR 6/4	7.5 YR 6/4		<input type="checkbox"/>
17 November	7.5 YR 6/4	fallen	7.5 YR 6/4		<input type="checkbox"/>
22 November	7.5 YR 6/4		fallen		<input type="checkbox"/>
29 November	7.5 YR 6/4				<input type="checkbox"/>
2 December	snow covered				<input type="checkbox"/>
					<input type="checkbox"/>

Check the last column on the green-down table when you report your observations to GLOBE.



Student Support

Scientific Justification

Growing plants use carbon dioxide from the air for photosynthesis. By removing this greenhouse gas from the atmosphere, plants play a major role in our planet's climate. Plants remove the carbon dioxide as they photosynthesize during the growing season, which may be only part of the year. Deciduous plants grow new leaves at the beginning of the growing season and lose their leaves at its end. They green-up and green-down. This wave of greenness is observed by satellites at the start and end of the growing season.

The greenness values detected by satellite sensors are important for scientists studying variations in global carbon dioxide amounts. The greenness values are also important for use by scientists and managers in mapping wildfire danger and for studying migration of wildlife such as caribou and waterfowl associated with greenness levels. Additionally, photosynthesizing plants transpire water which significantly affects atmospheric temperature, humidity, soil moisture and stream hydrology.

Satellites only give scientists estimates of when plants green-down across the continents. These estimates have many problems. For example, some satellite data are incorrect due to clouds and aerosols reducing the greenness value detected by the satellite sensor. It would be too time consuming and expensive for scientists to travel around the globe twice a week to observe where plants are green and where they have started to green-down. GLOBE schools can be a great help since they are already distributed around the globe and you can take important observations of green-down.

Synthesis Questions

What other animals (butterflies, waterfowl, songbirds) migrate after plants green-down? When? Why?

Does the timing of green-down occur earlier or later at higher elevations in your region? Why?

Does the timing of green-down occur earlier or later inland or near the coast in your region? Why?

How do fallen plant leaves affect soil properties such as soil color, water-holding capacity, and soil nutrients? How could you find out? Why is this important?



Tree and Shrub Green-Down Protocol

Field Guide

Task

Observe and record green-down in trees or shrubs.

What You Need

First visit only

- | | |
|---|--|
| <input type="checkbox"/> <i>Green-Down Data Sheet</i> | <input type="checkbox"/> Compass |
| <input type="checkbox"/> Pencil or pen | <input type="checkbox"/> Fine-Tip Permanent Marker |
| <input type="checkbox"/> Camera | <input type="checkbox"/> GLOBE Plant Color Guide |

Every visit

- | | |
|--|---|
| <input type="checkbox"/> GLOBE Plant Color Guide | <input type="checkbox"/> <i>Green-Down Data Sheet</i> |
| <input type="checkbox"/> Pencil or pen | |

In the Field

First visit only/getting started

1. Complete the upper portion of your data sheet.
2. Locate the leaf at the end of the branch. Label this leaf by marking one dot on the branch next to the leaf stem or petiole. Locate the three other leaves on this branch closest to this terminal leaf.
3. Label these leaves by marking two, three, or four dots next to their stems on the branch.
4. Take a photograph looking in the north, south, east, and west directions.

Every visit

1. Examine each of your four leaves. For each leaf, use the GLOBE Plant Color Guide to estimate the dominant color of each leaf. For example, if leaf 1 appears colored at 60 percent 5G 7/12 and 40 percent 2.5 Y8/10, record the leaf color as 5G 7/12 for that observation date.
2. Record your observations on the *Green-Down Data Sheet*.
 - If leaf is snow covered, report “snow covered”,
 - If leaf has fallen, report “fallen” and stop reporting after that,
 - Otherwise, continue to report the color until the color stops changing.

Grass Green-Down Protocol

Field Guide

Task

Observe and record green-down in grasses.

What You Need

- | | |
|---|--|
| <input type="checkbox"/> <i>Green-Down Data Sheet</i> | <input type="checkbox"/> Compass |
| <input type="checkbox"/> Pencil or pen | <input type="checkbox"/> Fine-Tip Permanent Marker |
| <input type="checkbox"/> Camera | <input type="checkbox"/> GLOBE Plant Color Guide |

Every visit

- | | |
|--|---|
| <input type="checkbox"/> GLOBE Plant Color Guide | <input type="checkbox"/> <i>Green-Down Data Sheet</i> |
| <input type="checkbox"/> Pencil or pen | |

In the Field

First visit only/getting started

1. Fill in the top of your data sheet.
2. Look for the four longest green grass shoots.
3. Mark the base of the longest grass shoot with a single dot. Mark the second longest shoot with two dots, the third with three dots and the fourth shoot with four dots.
4. Take a photograph looking in the north, south, east, and west directions.

Every visit

1. Examine each of your four leaves. For each leaf, use the GLOBE Plant Color Guide to estimate the dominant color percentage of each leaf. For example, if leaf #1 appears colored at 60 percent 5G 7/12 and 40 percent 2.5 Y8/10, record the leaf color as 5G 7/12 for that observation date.
2. Record your observations for each leaf on the *Green-Down Data Sheet*.
 - If leaf is snow covered, report “snow covered”,
 - If leaf has fallen, report “fallen” and stop reporting after that,
 - Otherwise, continue to report the color until the color stops changing.



Frequently Asked Questions

1. Should I use the same leaves I used for green-up?

If possible, use the same branches or grass plot. If you use other plants try to select plants of the same species. If the plants you use for green-down are at a different location than the ones you used for green-up, then define a new site.

Welcome

Introduction

Protocols

Learning Activities

Appendix